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Q1. (a) hydrofluoric acid

(b) hydrothiocyanic acid

(c) carbonic acid

(d) nitrous acid

(e) sulfuric acid

(f) persulfuric acid

Q2. (a) $HI(aq)$

(b) $HBr(aq)$

(c) $H_2Cr_2O_7(aq)$

(d) $HMnO_4(aq)$

(e) $H_2CO(aq)$

(f) $HNO_3(aq)$

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Q3. Acidic solutions: **(a)**, **(f)**; basic solutions: **(b)**, **(d)**; neutral solutions: **(c)**, **(e)**

Q4. Acidic solutions: conductive, pH below 7, sour taste; basic solutions: conductive, pH above 7, bitter taste; neutral ionic solutions: conductive, pH of 7, salty taste; neutral molecular solutions: non-conductive, pH of 7, variable taste but generally not sour, bitter, or salty.

Section 6.1 Review Answers

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1. (a) Three properties of an acid include a pH less than 7, conductivity, and a sour taste.

(b) Three properties of a base include a pH greater than 7, conductivity, and a bitter taste.

2. (a) Acids and bases must be treated with caution because they are corrosive and often toxic. Also, many acids and bases are clear and colourless, and can therefore be easily mistaken for water.

(b) Remind students to read and understand WHMIS labels and to wear safety glasses, gloves, and aprons. Ensure students know that acid should always be added to water when diluting; never water to acid. Review spill clean-up and reporting procedures. Students should know where to find eye wash stations, and should know that any acid or base spilled on skin should be immediately diluted with plenty of cool water.

3. (a) According to the Arrhenius theory of acids and bases, an acid is a substance that ionizes to form hydrogen ions in solution. A base dissociates to form hydroxide ions in solution.

(b) The Arrhenius theory can explain the conductivity of simple acids and bases that can ionize or dissociate to form OH^- or H^+ ions, such as HCl(aq) or NaOH(aq). The Arrhenius theory can also explain why different solutions have change in pH.

(c) The Arrhenius theory cannot explain why ammonia, NH_3(aq), exhibits basic properties since it does not contain a hydroxide ion that can dissociate.

(d) According to a modified Arrhenius theory in which water is introduced as a reactant, ammonia reacts with water to produce hydroxide ions:

$NH_3(aq) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH^-(aq)$

4. (a) $HCl(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + Cl^-(aq)$

(b) $HBr(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + Br^-(aq)$

(c) $HClO_4(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + ClO_4^-(aq)$

(d) $HNO_3(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + NO_3^-(aq)$

(e) Step 1: $CO_2(aq) \rightarrow H_2O(\ell) \leftrightarrow H_2CO_3(aq)$

Step 2: $H_2CO_3(aq) \rightarrow H_2O(\ell) \leftrightarrow HCO_3^-(aq) + H_3O^+(aq)$

5. (a) $NH_3(aq) + H_2O(\ell) \leftrightarrow NH_4^+(aq) + OH^-(aq)$

(b) $NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$

(c) $Ca(OH)_2(aq) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$

(d) $KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$

(e) Step 1: $SrO_{(s)} + H_2O(\ell) \rightarrow Sr(OH)_2(aq)$

Step 2: $Sr(OH)_2(aq) \rightarrow Sr^{2+}(aq) + 2OH^-(aq)$

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Q5. Strong acids: **(a)** and **(c)**, weak acids: **(b)** and **(d)**

Q6. Strong bases: **(b)** and **(d)**, weak bases: **(a)** and **(c)**

Q7. (a) Being a strong acid, HCl(aq) would have a higher concentration of hydronium ions.

(b) Being a weak acid, HF(aq) would have a lower conductivity

Section 6.2 Review Answers

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1. (a) The higher concentration of hydrochloric acid results in a higher hydronium ion concentration. Solutions with higher ion concentrations are better electrolytes and therefore have a higher conductivity.

(b) Sodium hydroxide is a strong base and dissociates completely. Ammonia is a weak base, and only a small percentage of the molecules react with water. Therefore, a 1.0 mol/L solution of sodium hydroxide contains a higher concentration of ions and a higher conductivity than a 1.0 mol/L solution of ammonia.

2. (a) hydrochloric acid, $HCl(aq)$

(b) sulfuric acid, $H_2SO_4(aq)$

(c) sodium hydroxide, $NaOH(aq)$

(d) sodium phosphate, $Na_3PO_3(aq)$

3. (a) acetic acid, $CH_3COOH(aq)$

(b) hydrochloric acid, $HCl(aq)$

(c) sodium hydroxide, $NaOH(aq)$

(d) ammonia, $NH_3(aq)$

(e) any Group 2 metal, such as calcium oxide, $CaO(s)$

(f) any of the oxides of sulfur, such as $SO_2(g)$, or of nitrogen, like $NO_2(g)$, which form sulfurous acid, $H_2SO_3(aq)$, and nitric acid, $HNO_3(aq)$, respectively

4. Formic acid is a weak acid.

5. Students should disagree with this statement. Both $H_2SO_4(aq)$ and $HCl(aq)$ are strong acids, but $H_2SO_4(aq)$ dissociates to form $HSO_4^-(aq)$, which is a weak acid. Only a small percentage of the $HSO_4^-(aq)$ ions react with water to form $SO_4^{2-}(aq)$. (They would need to react 100% for a 0.10 mol/L sulfuric acid solution to have double the hydronium ion content of a 0.10 mol/L hydrochloric acid solution.).

6. (a) neutralization **(b)** base **(c)** Na_2CO_3

(d) $Na_2CO_3(aq) \rightarrow Na^+ + CO_3^{2-}(aq)$

$CO_3^{2-}(aq) + H_2O(\ell) \leftrightarrow HCO_3^- + OH^-(aq)$

$HCO_3^- + H_2O(\ell) \leftrightarrow H_2CO_3^- + OH^-(aq)$

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For full solutions, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

1. (a) 2.57 **(b)** –0.716 **(c)** 11.082 **(d)** 4.01 **(e)** 3.792

2. 2.30 (acidic)

3. 3.54 (acidic)

4. 9.181

5. 2.201

6. 2.318

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Q8. The substance has a pH of between 2.8 and 4.8.

Q9. The solution should turn yellow.

Q10. Indigo carmine is blue at a pH of 11.4 and turns yellow at a pH of 13.0. At a pH of 12.0 indigo carmine should start to appear a blue–green colour and be completely green at 12.2. At a pH of around 12.5 indigo carmine ought to appear green–yellow in colour.

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For full solutions, visit **www.albertachemistry.ca,** Online Learning Centre, Instructor Edition, Full Solutions.

7. (a) 2.21 **(b)** –0.597 **(c)** 10.3 **(d)** 2.62 **(e)** 0.279 **(f)** 1.94

8. 5.70 (basic)

9. 3.60 (basic)

10. 2.460

11. 10.02

12. 3.564

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For full solutions, visit **www.albertachemistry.ca**, Online Learning Centre, Instructor Edition, Full Solutions.

13. (a) 1×10^{-4} mol/L (acidic)

(b) 1.7×10^{-9} mol/L (basic)

(c) 3.78×10^{-6} mol/L (basic)

(d) 4.5×10^{-12} mol/L (acidic)

14. 1.6×10^{-5} mol/L

15. 6.2×10^{-5} mol/L

16. 1.5×10^{-3} mol/L

17. 1.3 g NaOH(s)

18. 1.2×10^{-2} g HCl(g)

Section 6.3 Review Answers

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1. The pH system is a relatively easy way to discuss hydronium ion concentration without needing to use very small numbers and the accompanying negative exponents.
2. From least acidic to most acidic: egg white, camembert cheese, beets, yogurt, sauerkraut.
3. **(a)** 4.4–4.8 **(b)** 7.6 **(c)** 0.8
4. **(a)** pH = 7.40, base **(b)** pH = 1.40, acid
5. **(a)** pOH = 10.51, acid **(b)** pOH = 6.410, base
6. pH = 0.725
7. pH = 12.495
8. **(a)** $[H_3O^+(aq)] = 1.7 \times 10^{-3}$ mol/L
   (b) $[H_3O^+(aq)] = 2.70 \times 10^{-4}$ mol/L
9. **(a)** $[OH^-(aq)] = 1.1 \times 10^{-4}$ mol/L
   (b) $[OH^-(aq)] = 8 \times 10^{-5}$ mol/L
10. $[HNO_3(aq)] = 5.4 \times 10^{-3}$ mol/L
11. 4.4×10^{-3} g KOH(s)
12., 13. ICT may vary

Range of acidity and basicity	$[H_3O^+(aq)]$ (mol/L)	pH (= –log $H_3O^+(aq)$]	$[OH^-(aq)]$ (mol/L)	pOH (=14 – pH)
very acidic	1.0	0	0.000 000 000 000 01	14
	0.1	1	0.000 000 000 000 1	13
	0.01	2	0.000 000 000 001	12
	0.001	3	0.000 000 000 01	11
	0.000 1	4	0.000 000 000 1	10
	0.000 01	5	0.000 000 001	9
	0.000 001	6	0.000 000 01	8
neutral	0.000 000 1	7	0.000 000 1	7
	0.000 000 01	8	0.000 001	6
	0.000 000 001	9	0.000 01	5
	0.000 000 000 1	10	0.0001	4
	0.000 000 000 01	11	0.001	3

Range of acidity and basicity	$[H_3O^+(aq)]$ (mol/L)	pH (= –log $H_3O^+(aq)$]	$[OH^-(aq)]$ (mol/L)	pOH (=14 – pH)
	0.000 000 000 001	12	0.01	2
	0.000 000 000 000 1	13	0.1	1
very basic	0.000 000 000 000 01	14	1	0

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Answers to Understanding Concepts Questions

1. Acids: low pH, conductivity, sour taste
   Bases: high pH, conductivity, bitter taste
2. **(a)** According to the modified Arrhenius theory an acid must be capable of producing hydronium ions in solution, usually through the loss of hydrogen atoms. A base must be capable of producing hydroxide ions.
   (b) The presence of hydronium or hydroxide ions makes the solutions conductive.
   (c) An acid loses hydrogen atoms to water, forming hydronium ions.
   (d) A base forms hydroxide ions in water.
   (e) Strong acids and bases dissociate completely into hydronium and hydroxide ions, whereas weak acids and bases only produce small amounts of these ions.
   (f) The pH of a solution is dependent on the concentration of hydronium ions.
   (g) The pOH of a solution is dependent on the concentration of hydroxide ions.

3. $NaOH(aq) + HNO_3(aq) \rightarrow H_2O(\ell) + NaNO_3(aq)$

4. **(a)** weak acid **(b)** weak acid

(c) strong base **(d)** weak base

5. Diprotic means that the acid has two hydrogen ions (or protons) that it can donate in solution.

6. $H_2SO_4(aq)$ is a strong acid as it dissociates 100%. $HSO_4^-(aq)$ dissociates less than 50% and is a weak acid.

7. **(a)** basic **(b)** neutral **(c)** acidic

8. An acid–base indicator is a substance that changes colour with a change in pH.

9. Universal indicator undergoes many different colour changes with small changes in pH, whereas bromothymol blue only undergoes two, yellow to blue, with the solution turning green in between endpoints.

10. Universal indicator relies on colour changes, which are a subjective measurement since they can change in intensity or under different lighting. Moreover, people tend to

classify shades of colours differently. Colour-blind people have problems distinguishing between different colours. A pH meter displays a calculated pH value, making it more accurate.

11. **(a)** pH = 2.900, acid **(b)** pH = 5.450, acid
(c) pH = 12.010, base

12. **(a)** pOH = 6.100, base **(b)** pOH = 6.631, base
(c) pOH = 9.290, acid

13. **(a)** $[H_3O^+(aq)] = 1.1 \times 10^{-5}$
(b) $[H_3O^+(aq)] = 3 \times 10^{-11}$
(c) $[H_3O^+(aq)] = 1.7 \times 10^{-11}$
(d) $[H_3O^+(aq)] = 1 \times 10^{-12}$
(e) $[OH^-(aq)] = 2.8 \times 10^{-13}$
(f) $[OH^-(aq)] = 6 \times 10^{-3}$
(g) $[OH^-(aq)] = 2 \times 10^{-7}$
(h) $[OH^-(aq)] = 2 \times 10^{-3}$

Answers to Applying Concepts Questions

14. The hydrochloric acid has the lowest pH as it is a strong acid, while the acetic acid has the next lowest since it is only a weak acid. The ammonia solution is a weak base and so has the highest pH.

15. The low pOH of codeine indicates it has a high concentration of $OH^-(aq)$ ions, making it a base.

16. Diluting an acid tenfold raises the pH by a value of 1. Diluting one hundredfold raises it by 2. As you continue to dilute the acid, its pH will steadily approach 7. With further dilution the acid's pH will remain at 7, since the autoionization of water dominates.

17. **(a)** 5.4–6.0 **(b)** 8.0–8.2 **(c)** 10–11.4

18. **(a)** yellow **(b)** yellow–green **(c)** yellow

19. The cheese is not safe to eat, since its pH of 7 is too high.

20. Students ought to design a procedure to test pH and conductivity. The strong acid, strong base, and neutral ionic solutions should have a high conductivity. The weak acids and bases should have a low conductivity, while the neutral molecular solution should have no conductivity. The neutral solutions should have a pH of 7, the strong acid should have a low pH, while the weak acid should be just below 7. The strong base should have a high pH and the weak base should have a pH just above 7.

21. When dealing with pH, or any logarithm, significant digits are counted after the decimal. For example, a pH value of 7.5 has only one decimal digit, while a pH value of 9.43 has two.

22. This answer depends on the concentration of the two substances. At equal or similar concentrations, since the strong acid dissociates 100%, it generates far more hydronium ions than the weak acid, giving it a far greater reactability, or strength. The weak acid would have to be significantly more concentrated than the strong acid to have the same strength.

23. Since the hydrochloric acid dissociates 100% as a strong acid, it will generate 1.0 mol/L of hydronium ion. Acetic acid is a weak acid and will generate approximately 0.01 mol/L of hydronium ion. While both of these solutions will react with magnesium, producing hydrogen gas as bubbles, the rate of bubbling will be much greater with the hydrochloric acid.

Answers to Solving Problems Questions

24. pH = 4.046

25. pH = 10.281

26. 0.091 g $HI(\ell)$

27. 4×10^{-3} g $HNO_3(\ell)$

28. 9 g $KOH(\ell)$

Answers to Making Connections Questions

29. Limestone contains calcium carbonate, $CaCO_3(s)$, which must be a base since it protects lakes from changes in pH due to acid rain. Although calcium carbonate does not contain the hydroxide ion, $OH^-(aq)$, it reacts with water to produce hydroxide ions. This base will neutralize the acid in acid rain, protecting the lake.

30. **(a)** $CO_2(aq) + H_2O(\ell) \rightarrow H_2CO_3(aq)$

(b) Carbonic acid is a relatively weak acid and the acids that make up acid rain are stronger.

(c) Most acid rain comes from industrial pollutants, more abundant in Eastern Canada.

(d) During combustion of coal, sulfur reacts with oxygen to form (principally) sulfur dioxide, $SO_2(g)$. This in turn dissolves in and reacts with water in the atmosphere to form dilute sulfurous acid:

$SO_2(aq) + H_2O(\ell) \rightarrow H_2SO_3(aq)$

(e) Scrubbers work by neutralizing the sulfur dioxide gas with calcium oxide:

$SO_2(g) + CaO(s) \rightarrow CaSO3(s)$

The calcium sulfite is water-soluble and can be washed away.

(f) Answers may include: using alternative forms of transit to cars, driving a car with greater fuel economy (e.g., not an SUV or truck), economizing use of electricity (generated mostly by burning fossil fuels), reusing and recycling paper.

31. The formation of carbonic acid from respiration causes the bromothymol blue to turn yellow.